Cavehopping Exploration of Planetary Skylights and Tunnels

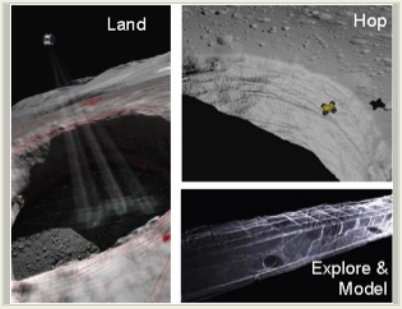
Completed Technology Project (2012 - 2014)

Project Introduction

The robots that venture into caves must leap, fly, or rappel into voids, traverse rubble, navigate safely in the dark, self-power, and explore autonomously with little or no communication to Earth. Exploiting these features necessitates a "leap" of technology from current planetary missions, which will be advanced by this team. Subsurface caverns may be the best place on Mars to find life. They may be the best hope for safe havens and habitation on the Moon. They can provide a window into a planet's geology, climate, and even biology. Skylights, formed by partial cave ceiling collapse, provide access to subsurface voids. Tunnel entrances have been conclusively shown to exist on Mars and the Moon. There is also evidence supporting their existence on other planetary bodies throughout the solar system. Despite astonishing discoveries of skylights and cave entrances, and their inevitable exploration, they do not yet appear in the decadal survey. Skylights and the voids below are so unknown that it is too risky to send astronauts to explore them without prior robotic reconnaissance and modeling. While robotic exploration of skylights and caves can seek out life, investigate geology and origins, and open the subsurface of other worlds to humankind, it is a daunting venture. Planetary voids present challenging terrain that requires innovative technologies for access, exploration, and modeling. The robots that venture into caves must leap, fly, or rappel into voids, traverse rubble, navigate safely in the dark, self-power, and explore autonomously with little or no communication to Earth. Exploiting these features necessitates a "leap" of technology from current planetary missions, which land with large error ellipses in statistically safe terrain, rove slowly and cautiously across the surface, depend on the sun for power and light, and rely heavily on human commands. Phase II develops the enabling technologies in the context of "Spelunker", a prototype mission concept to explore a lunar skylight and cave. The Spelunker mission specifies safe landing on the rim of a skylight, tethered descent of a power and communications hub, and autonomous cave exploration by multiple hybrid driving/hopping robots. In this context, the Phase II study will expose and address major feasibility issues inherent in mission architecture for skylight access; robot configuration for in-cave mobility and subsurface sensing; terrain modeling in darkness from a lightweight, dynamic platform; and autonomy for exploring with hopping robots.

Anticipated Benefits

Pits and caves are opportunistic study targets for unique origins, geology, and climate that will broadly impact planetary science. Holes on Mars are of particular interest because their interior caves are relatively protected from the harsh surface, making them good candidates to contain Martian life. Pits are prime targets for possible future spacecraft, robots, and even human interplanetary explorers. Caves and caverns could be ready-made shelters for future Moon and Mars explorers and colonists.



Project Image Cavehopping Exploration of Planetary Skylights and Tunnels

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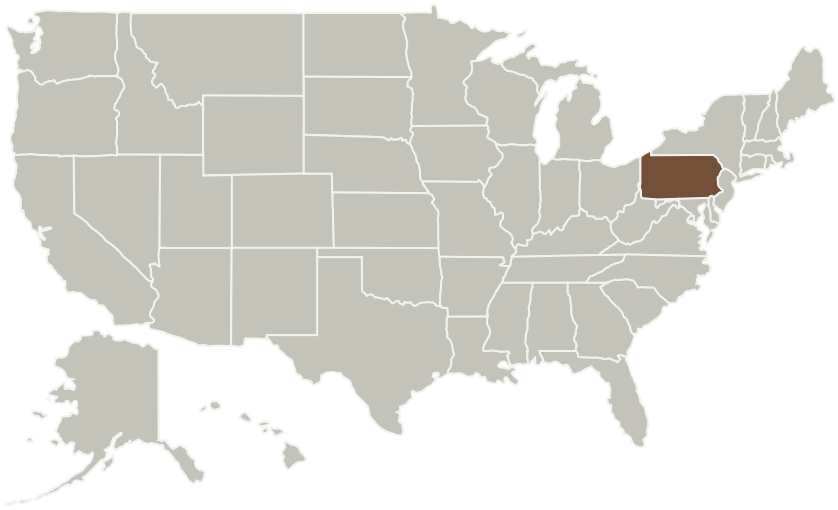
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Astrobotic Technology, Inc.	Lead Organization	Industry	Pittsburgh, Pennsylvania
Carnegie Mellon University	Supporting Organization	Academia	Pittsburgh, Pennsylvania

Primary U.S. Work Locations
Pennsylvania

Project Transitions

September 2012: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Astrobotic Technology, Inc.

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

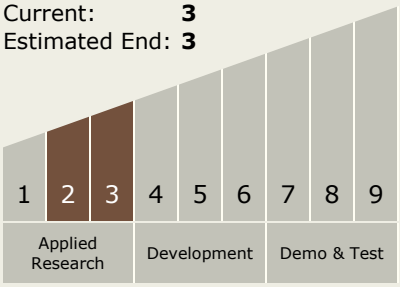
Eric A Eberly

Principal Investigator:

William Whittaker

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



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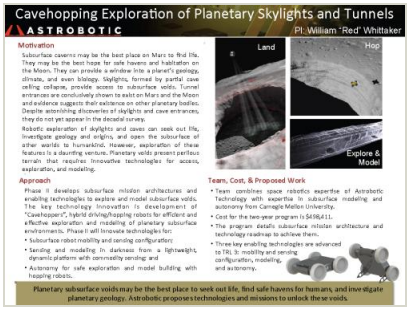
Completed Technology Project (2012 - 2014)

September 2014: Closed out

Closeout Summary: Pits and caves are opportunistic study targets for unique o rigins, geology, climate, and astrobiology that will broadly impact planetary scie nce. Although missions for deep-\xac-cave access require substantial developme nt, minimalist near-\xac-term missions could yield great gains. In these mission s, pits can be modeled from bird's eye view during lander flyover at much great er resolution and accuracy than achievable from orbit and at close enough range for active illumination techniques such as LIDAR. Pits can be modeled by robot c ircumnavigation at even greater resolution and accuracy, with access to lower vi ew angles and varied lighting conditions. Robotic missions can access the full ra nge of pit morphologies. Pits can be accessed through flyover, perimeter travers e, Tyrolean lines, and free or tethered descent. Some pits offer ramps for possib le rover descent without specialized descent mechanisms. Small, battery-\xac-p owered, wheeled rovers can explore caves and lava tubes. Innovative technique s based on mathematical models of the physics of light, such as Lambertian algo rithms, improve pit and cave models by an order of magnitude. Good pit models can be constructed from images only. Time history of illumination must be consi dered in planning robotic pit exploration routes. Experimental methods in this re search compare results of innovative techniques with ground truth survey. The s tudy of pits and voids lays a foundation for human exploration of planetary bodi es. Voids such as caves and tubes that are accessible through pits may provide shelter from harsh planetary environments, reducing the complexity of human s urvival beyond Earth. That is authentic exploration. Robots must precede human s, since the promise of caves is tempered by their great unknown. Safety and vi ability must be insured before humans explore and utilize these enchanting, inv aluable destinations. Much discovery awaits below the surface. Subsurface explo rers may discover signs of life, origins and resources, and possibility of havens u nseeable from orbit. Robots and technologies envisioned here will explore, pione er, and prepare our way to the subsurface worlds that await beyond Earth.

Images



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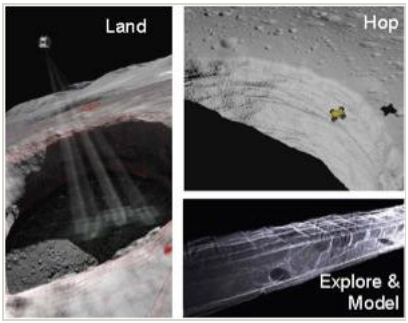
Project Image Cavehopping Exploration of Planetary Skylights and Tunnels
(https://techport.nasa.gov/image/102232)



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Project Image Cavehopping Exploration of Planetary Skylights and Tunnels
(https://techport.nasa.gov/image/102235)

Technology Areas

Primary:

- TX04 Robotic Systems
  - TX04.2 Mobility
    - TX04.2.1 Below-Surface Mobility

Target Destinations

The Moon, Mars